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ROLE OF ORIENTATION REFERENCE SELECTION
IN MOTION SICKNESS

Semiannual Status Report
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REFERENCE SELECTION IN MOTION SICKNESS
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Summary of Proposal

Previous experiments with moving platform posturography have shown that different people have varying abilities to resolve conflicts among vestibular, visual, and proprioceptive sensory signals. In particular, there is one class of subjects with a vestibular disorder known as benign paroxysmal positional vertigo (BPPV) who often are particularly sensitive to inaccurate visual information. That is, they will use visual sensory information for the control of their posture even when that visual information is inaccurate and is in conflict with accurate proprioceptive and vestibular sensory signals. BPPV has been associated with disorders of both posterior semicircular canal function and possibly otolith function. The conceptual basis of the present proposal hinges on the similarities between the space motion sickness problem and the sensory orientation reference selection problems associated with the BPPV syndrome. These similarities include both etiology related to abnormal vertical canal-otolith function, and motion sickness initiating events provoked by pitch and roll head movements.

The objectives of this proposal were developed to further explore and quantify the orientation reference selection abilities of subjects and the relation, if any, between motion sickness and orientation reference selection. The overall objectives of this proposal are to determine (1) if motion sickness susceptibility is related to sensory orientation reference selection abilities of subjects, (2) if abnormal vertical canal-otolith function is the source of these abnormal posture control strategies and if it can be quantified by vestibular and oculomotor reflex measurements, and (3) if quantifiable measures of perception of vestibular and visual motion cues can be related to motion sickness susceptibility and to orientation reference selection ability demonstrated by tests which systematically control the sensory information available for orientation.

Summary of Project Status

Three test devices are required for the proposed experiments. They are (1) moving posture platform, (2) servo controlled vertical axis rotation chair with an independently controllable optokinetic stimulator, and (3) servo controlled, hydraulic powered two-axis rotation chair for the generation of pitch and roll motions. The first two devices are currently functional and are routinely used for both clinical and research testing. The third device is under development. The development of the this two-axis rotator has been a major focus in the first half of this project year and will be described in more detail below.

The second major focus was to begin preliminary experiments using the perceptual feedback technique developed by Zacharias and Young (Exp Brain Res, 41:159-171, 1981). This project required both hardware modification of electronics for our vertical axis rotation chair and development of software for the control of the experiment and data collection, and software for the analysis of the data.

Two-axis Rotator Development

The two-axis rotator has been under development for the past two years. Most of the funds for this development came from startup money associated with the PI's move to Good Samaritan Hospital. Additional funds in the current NASA project are supporting the final phases of development. Figure 1 shows a line drawing of the rotator. It consists of two gimbals powered by rotary hydraulic actuators. The inner gimbal produces yaw axis rotations of the subject. The outer gimbal rotates the subject about a horizontal axis which passes through the subject's ears. Figure 2 shows photographs of the two-axis rotator taken on February 9, 1987 in a machine shop in Pittsburgh, PA where it was constructed. The device has since been shipped to us and we have begun its installation. We have been preparing for the arrival of the device by constructing the electronic circuits necessary for the hydraulic servo system. These circuits have been completed for the yaw axis drive, and are 90% completed for the pitch axis drive. The control circuits provide for both position and velocity servo control loops, and the ability to switch between the loops under computer control. The circuits include an adjustable compensation network which can fine tune the dynamic properties of the servo loops. Additional circuits have been completed for the buffering and scaling of position and velocity signals from the yaw and pitch actuators, and a safety shutdown circuit which shunts the hydraulic supply pressure and turns off the pump if either of the axes move out of range. Additionally there are fluidic shock absorbers to cushion the stop if the device were to go out of control.

A preliminary stimulus control program has been written for the LSI 11/73 computer which interfaces with the two-axis rotator. The program provides for turning on and off hydraulic power, switching between position and velocity servo loop modes, zeroing of drift in velocity mode, and delivering sinusoidal and square wave stimuli. This program is currently used for calibrating and adjusting servo loop compensation networks. The program will later be expanded into a full data collection and stimulus control program.

Perceptual Feedback Experiments

In 1981, Zacharias and Young presented a method which allowed for the quantification of a subject's perception of rotation under the combined influence of visual and vestibular cues. In this technique, the subject has control over the rotational motion of the chair by adjusting a potentiometer. The subjects are seated in the vertical axis rotation test room with the potentiometer mounted on the arm of the chair. The output of this potentiometer is summed with the velocity command signal from a computer and this summed signal is delivered to the velocity command input of the chair's servo motor. A "perfect" subject would be able to hold themselves stationary in space by adjusting the potentiometer so that its output was equal but opposite to the computer's command signal. "Real" subjects do not remain stationary because of the dynamics of the motion perception and motor reaction systems, and because of presumed imbalances in the vestibular receptors.

The rotation of the subject's chair and the visual surround can be independently manipulated. We have used 6 different sensory environments for our preliminary experiments. These include (1) chair rotation in the dark, (2) rotation of the visual surround with the chair stationary, (3) chair rotation

with the visual surround velocity equal to the chair velocity, (4) chair rotation with a constant velocity surround, (5) chair rotation with the velocity of the visual surround equal to the chair velocity plus a constant, and (6) chair rotation with a stationary visual surround. Condition (2) is used to test the motor control dynamics of the subject. Conditions (1) and (3)-(6) represent a variety of sensory environments in which the subject is forced to deal with either accurate, inaccurate, conflicting, or absent sensory cues about their motion.

The hardware has been modified in our vertical axis rotation test room to accommodate these perceptual feedback experiments. Additionally we have written a stimulus control and data collection program for these experiments. We can define either a sum-of-sines or pseudorandom stimulus or a single frequency sinusoidal stimulus which the subject must balance out under the various sensory environments. The program collects 6 channels of data at 100 samples per second. These channels include chair velocity, optokinetic projector velocity, chair command velocity (from the computer), optokinetic projector command velocity, the subject's feedback potentiometer signal, and horizontal eye position recorded from an EOG amplifier. This data is stored in a disk file for later analysis. We have also written a preliminary data analysis program which at this point consists of simply printing out and labeling the six channels of data from the various test conditions.

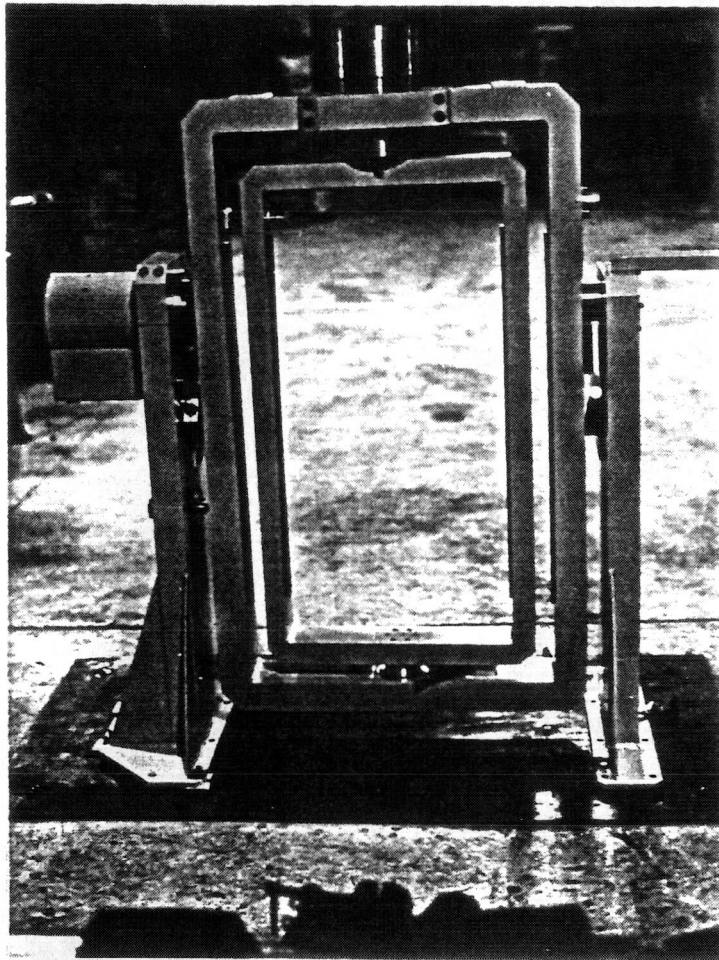
Results from three different subjects under condition (1), rotation in the dark, are shown in Figures 3-5. One of these subjects was able to remain nearly stationary throughout the test (Figure 3, top trace). The other two, shown in Figures 4 and 5, drifted slowly to the left. These results are similar to those obtained by Zacharias and Young, although they did not test their subjects in a dark environment. This drift was attributed to possible biases introduced by imbalances between the two ears.

The goal of these preliminary experiments is to (1) gain experience with this technique, (2) verify the results of Zacharias and Young, (3) extend the results of Zacharias and Young by including additional sensory environments, and (4) determine the consistency of results for individual subjects tested over time. These techniques will later be extended to the two-axis rotator, compared with results of moving platform posturography, and correlated with the results of vestibular and oculomotor reflex measurements and measurements of motion sickness susceptibility.

Additional Work

We have purchased a small servo motor, controller, and power supply for use in an optokinetic stimulator for the two-axis rotation device. The design of this projector is nearly completed and parts for its construction have been ordered. This projector will be movable in order to allow both horizontal or vertical motions of the visual stimulus.

Other efforts include the completion of the data analysis of the 200 normal subjects. Data from these subjects was collected as part of previous NASA projects (NCC9-8 and NAG 9-117). A paper based on this data was presented at the Association for Research in Otolaryngology meeting in February 1987. A copy of this abstract is attached at the end of this report. Two papers for publication are nearly completed, and will be submitted to Experimental Brain Research in the next month.



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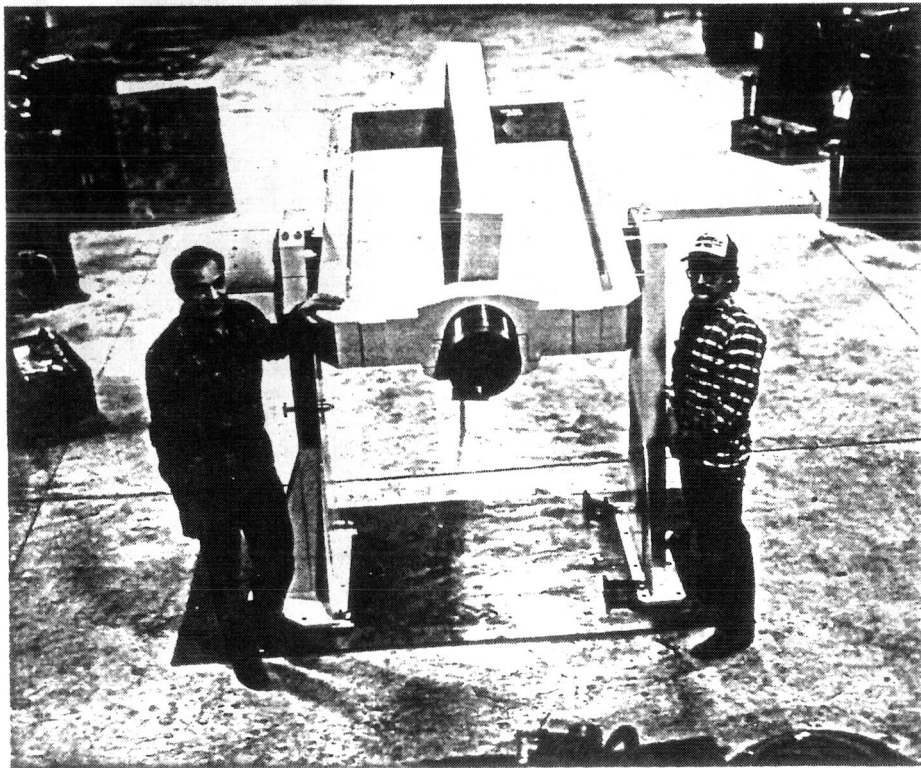
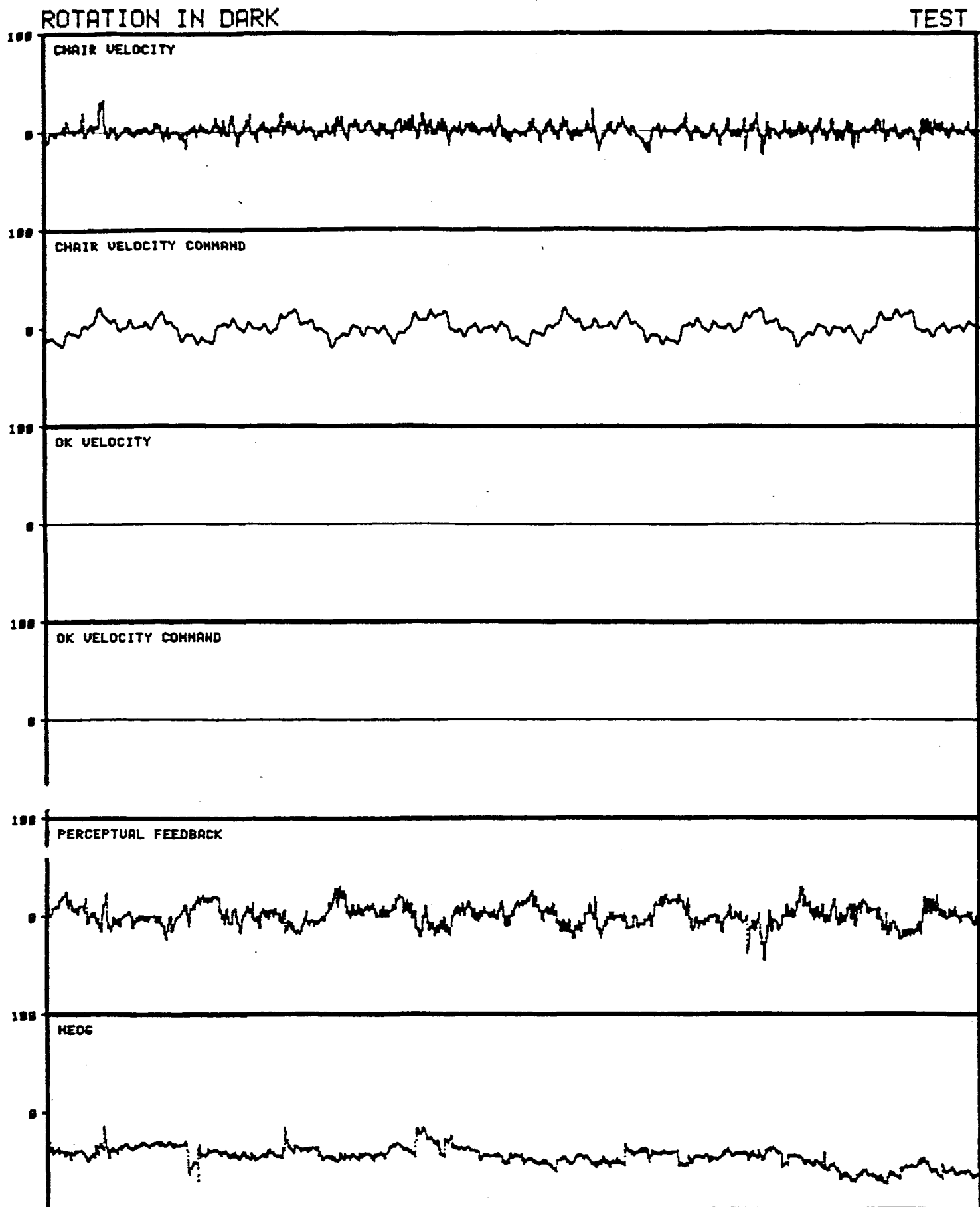


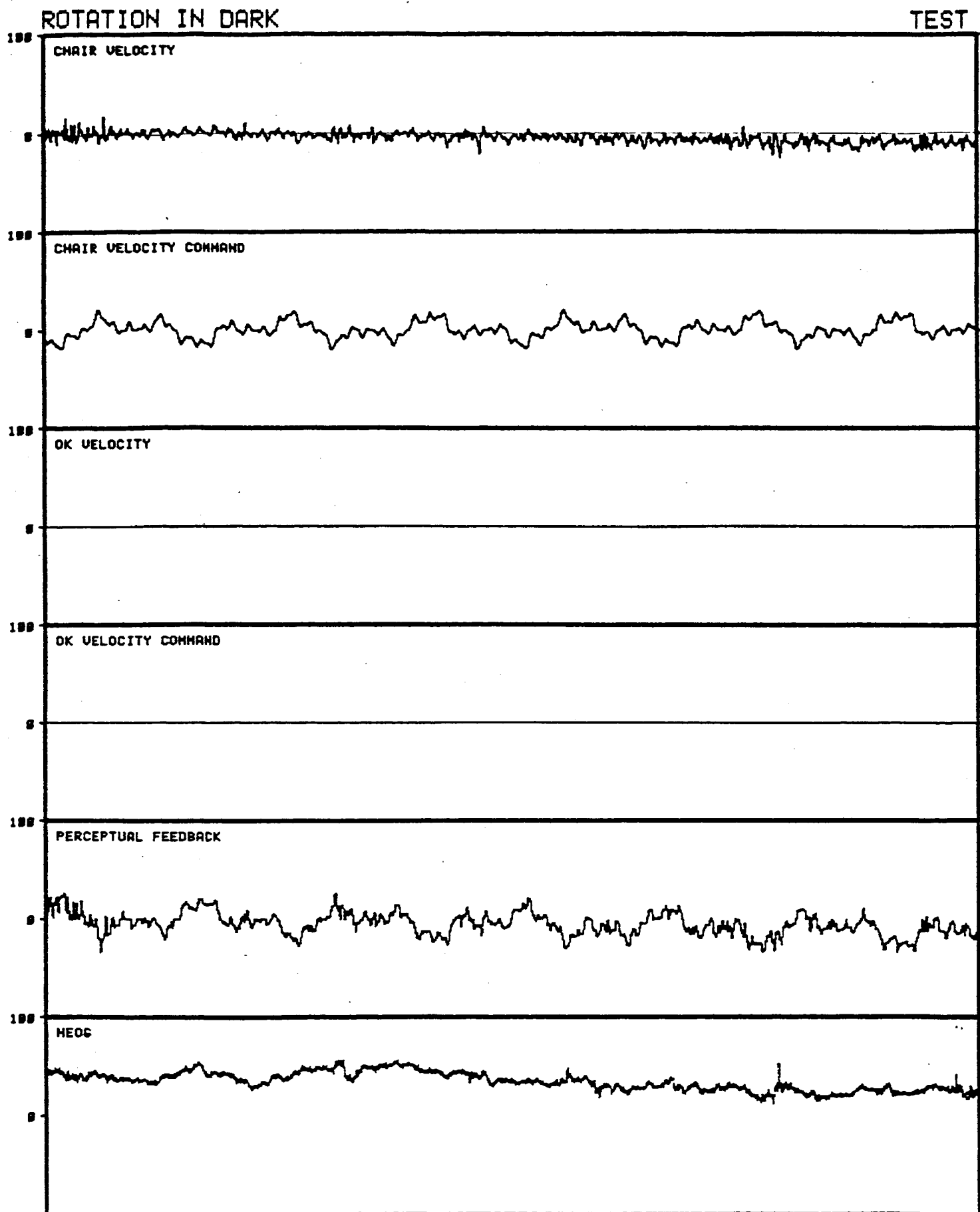
Figure 2



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Subject #1

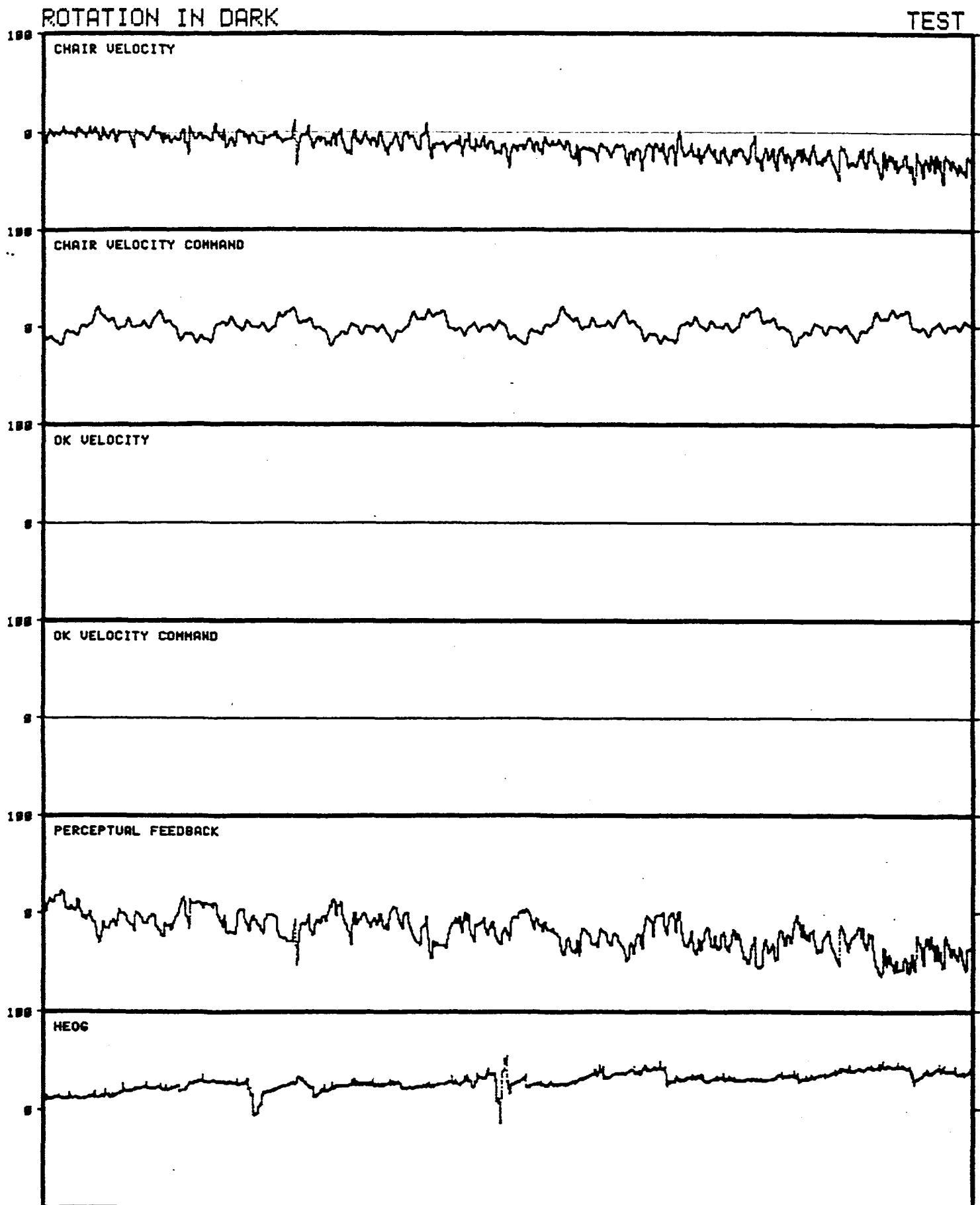
Figure 3



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Subject #2

Figure 4



NAME:
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Subject #3

Figure 5

AGE RELATED CHANGES IN HUMAN VESTIBULOOCULAR AND VESTIBULOSPINAL REFLEX FUNCTION. *R.J. Peterka, F.O. Black, C.D. Newell, and M.B. Schoenhoff. Neurological Sciences Institute and Department of Neuro-otology, Good Samaritan Hospital and Medical Center, Portland, Oregon 97210.

The function of the vestibuloocular reflex (VOR) and vestibulospinal (VS) systems was tested in 216 normal human subjects aged 7 to 81 years. The distribution of ages was nearly uniform. All subjects met criteria which included normal age corrected auditory function, negative histories of dizziness or equilibrium problems, neurological problems, ototoxic drug use, or head blows of sufficient magnitude to cause loss of consciousness or skull fracture. Subjects were not rejected based on vestibular test results.

VOR tests were performed in the dark and included sinusoidal rotations about a vertical axis at 0.05, 0.2, and 0.8 Hz and a pseudorandom stimulus consisting of the summation of 8 sinusoidal components from 0.01 to 1.5 Hz. Slow phase eye velocity responses were analyzed to obtain VOR gain, phase, average value, and asymmetry.

VS testing was performed with a subject standing on a platform and within a visual field enclosure. Both the platform and visual field could be independently rotated about the ankle joint axis. The anterior-posterior body sway of the subject was monitored by a potentiometer with a wand attached at the subject's hip. Each subject was asked to stand during six 20 second trials during which they were exposed to various combinations of eyes open, eyes closed, and platform and/or visual field rotations. Platform and visual field rotations were always in the direction of and in proportion to the subject's actual body sway. Rotations of this type limit the proprioceptive and visual sensory information available for the control of posture.

Age related trends were observed in both VOR and VS function. There were significant VOR gain decreases at all test frequencies and phase increases at 0.2 Hz and above with increasing age. There was a small but insignificant decrease in the VOR time constant with an associated small increase in low frequency phase leads. All trends in VOR response parameters were small with respect to the overall variability of the data. Decreasing VS function with increasing age was revealed by the increased number of falls on two or more of the six posture test trials. Subjects 60 and older accounted for 54% of these falls. The pattern of falls was not random, but occurred mostly on two pairs of trials. One pair consisted of trials in which the visual field rotated in proportion to the subject's sway indicating that these subjects relied primarily on vision for the control of their balance. The other pair consisted of trials in which both proprioceptive and visual information were removed forcing the subject to use only vestibular cues.

Subjects who fell two or more times during VS testing were more likely to have VOR response parameters on the fringes of the population distributions. This indicates that subjects who fell on two or more trials had vestibular function which was impaired with respect to the remainder of the population. Within this selected normal population, one could reasonably conclude that about 10% of the population had significant functional vestibular deficits, and that most of these deficits occurred in older subjects.

(Supported by NASA grants NCC 9-8 and NAG 9-117)

Abstract of paper presented at Tenth Association for Research in Otolaryngology Meeting, February 1987